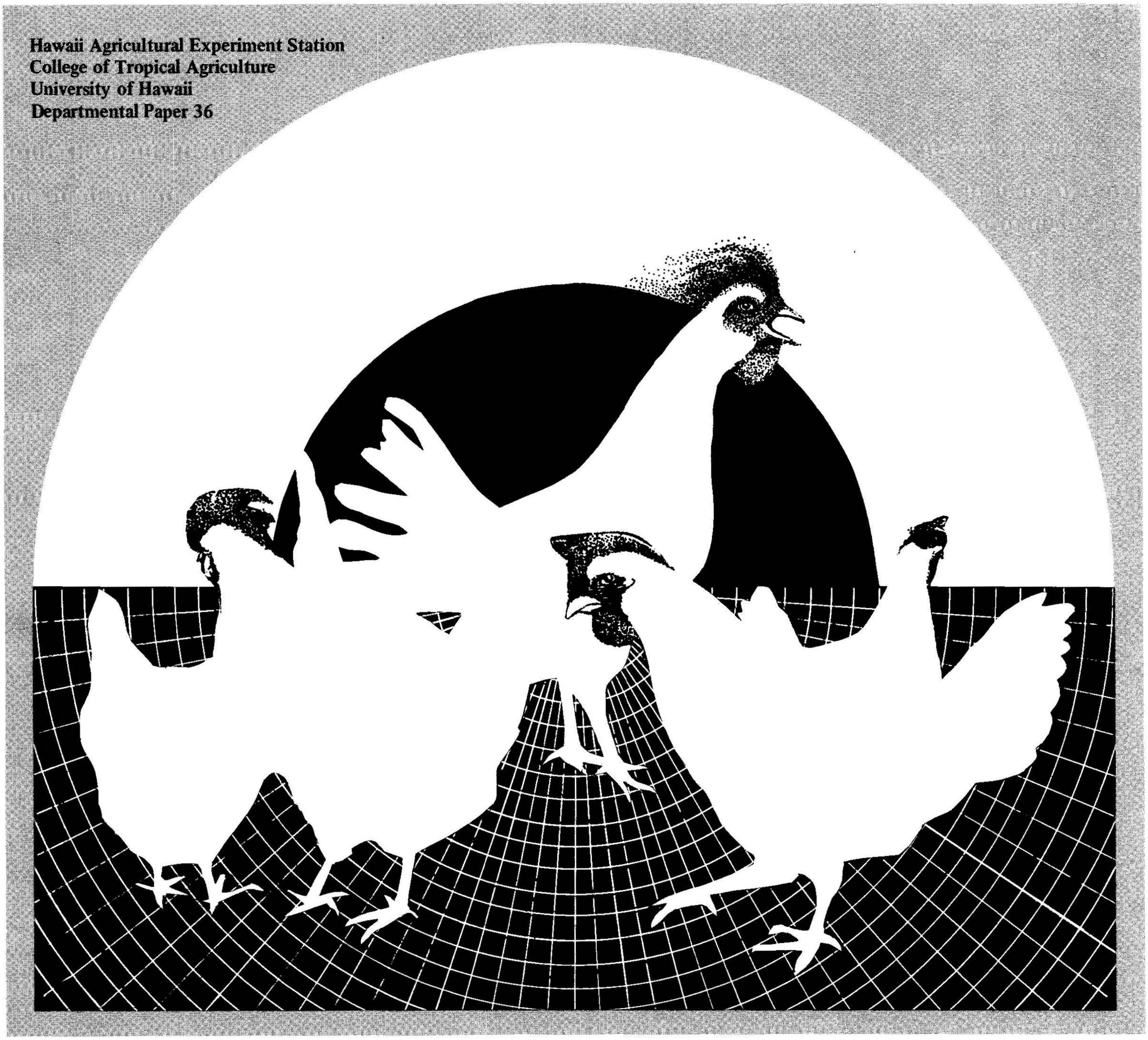
Hawaii Agricultural Experiment Station
College of Tropical Agriculture
University of Hawaii
Departmental Paper 36



ENCLOSED LAYER HOUSING IN HAWAII

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ABSTRACT

Performance of laying hens in enclosed housing with mechanically controlled ventilation set to provide either high (8-13 cfm per bird) or low (4.5-6 cfm per bird) ventilation rates or naturally ventilated open-sided housing was compared. Leghorn hens housed in 12 x 18 inch cages at the rate of 3 birds per cage were started on experiment at 22 weeks of age. During the 52-week experimental period data were collected on egg production, feed efficiency, body weight gain, egg weight, albumen quality, shell thickness, percent cracked eggs and mortality rate. Mean hen-day egg production was 63.3, 65.0 and 66.2 percent for birds housed in the enclosed houses with high and low ventilation rates and the open-sided house, respectively. These values did not differ significantly. Pounds of feed required to produce a dozen eggs averaged 3.98, 3.96 and 4.15 for birds housed in the enclosed houses with high and low ventilation rates and the open-sided house, respectively. These differences were not statistically significant. There were no significant differences in body weight gains among hens maintained in either of the enclosed houses or in the open-sided house; nor were there any significant differences among weights, interior quality or shell thickness of eggs produced by birds in the three environments. Significantly more cracked eggs were produced by birds in the enclosed houses. Percentage of cracked eggs averaged 7.11, 6.66 and 5.97 among eggs laid by birds in the enclosed houses with high and low ventilation rate and the open-sided house, respectively. Mortality rates did not differ significantly among birds in any of the three houses, although mortality was higher among birds in the open housing as compared to mortality of birds in either enclosed house. Income per bird housed over pullet, feed and electricity costs from maintaining birds in the enclosed houses with high and low ventilation rate was $2.49 and $2.72 per bird, respectively, and $2.52 per bird maintained in the open house.

INTRODUCTION

There is growing interest in the application of enclosed poultry housing in areas with moderate climates (Drury, *et al.*, 1964; Harwood, 1972; and Parsons and Bell, 1968). Advantages claimed for enclosed housing in these areas include the reduction of noxious odors (including ammonia) and fly populations, reduction of adverse effects of wind and provision for more uniformity of air movement, minimization of morbidity and mortality and maximization of feed efficiency among laying hens. If cooling is provided, temperature control is possible; however, even without provisions for controlling temperature, enclosed housing may improve layer performance and reduce certain nuisance factors associated with commercial egg production which is especially important in areas of urban encroachment.

Previous work in Hawaii (Herrick and Ross, 1974) has shown that enclosed housing improved layer efficiency, however, the temperature-humidity index was higher in the enclosed layer houses than in the open-sided house. Although the environment in the enclosed houses was not considered detrimental to hen performance, modifications in enclosed house design were considered necessary to reduce the solar heat load on the house and thereby improve environmental conditions within the house. This study was designed to investigate methods to improve the enclosed poultry house environment and to collect additional information on the operation of controlled light and air poultry housing under Hawaiian conditions.

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MATERIALS AND METHODS

Pullet chicks of a commercial White Leghorn strain were reared under similar conditions of management. At 20 weeks of age, they were transferred to 12 x 18 inch cages in three experimental houses. An enclosed house, 24 x 96 feet, was partitioned into two separate units 24 x 48 feet. The third house was an open-sided conventional poultry house. All three houses had exterior galvanized roofs painted first with primer and then with a white light-reflecting paint. Both enclosed houses had the sidewalls enclosed with 1/4-inch plywood with two 2½-inch air intake slots, designed to provide a high degree of light blockage, extending continuously along both sides of the building. One air intake slot was located below the ceiling level and the other was located one foot above the floor level. A full ceiling in each enclosed house separated the cage area below from the attic area above in a normal type of gable-roof design. One 3/4 H.P., 2-speed, 24-inch exhaust fan was installed in each attic end wall exhausting the attic air. Rectangular 6 x 20 inch openings were cut in the plywood ceilings in a regular pattern down each alleyway between the rows of cages. The ceiling vents were provided with adjustable covers to permit control of air velocity. The air flow through each vent was adjusted to provide an even air flow throughout the cage area. Once the initial adjustment was made in the ceiling vents, they were not changed during the course of the study.

Ventilation systems in both enclosed houses were similar as air was drawn through the air intake slots into the cage area and then was drawn into the attic area through the ceiling air vents and finally exhausted through the fans at the attic end walls.

There was a difference in ventilation rate, however, between the two enclosed houses as the exhaust fans in each house were set at different speeds. In the house hereafter designated high ventilation rate house, the fan was adjusted to provide 13 cfm per bird at high speed and 8 cfm per bird at low speed while the fan in the other enclosed house was set to provide a lower air velocity of 6 cfm per bird at high speed and 4.5 cfm per bird at low speed (hereafter designated low ventilation rate house). A differential thermostat for the fan in each enclosed house was set so fans would be on high speed when the cage area temperatures exceeded 83°F. All other aspects of the building design and ventilation system were identical in the two enclosed houses.

Each experimental house (the two enclosed houses and the open-sided house) contained six rows of 32 cages. Each row was divided into four blocks (replicates) of eight cages each making a total of 24 blocks containing 192 cages in each experimental unit. Birds were randomly assigned at the rate of three birds per cage, making a total of 24 birds per block and 576 birds in each of the three experimental houses.

The birds were kept in these cages during the 52-week experimental period which commenced when the birds were 22 weeks of age (Dec. 14, 1971). During the experiment, the birds were given feed and water _ad libitum_ and provided with 14 hours of light per day. The light intensity in the enclosed house was reduced with a dimmer switch to less than one-foot candle except for short periods during the day when feed was added or eggs collected, at which time an over-ride switch allowed full illumination. Birds in the open house received 14 hours of a combination of natural light supplemented with artificial light which averaged over three-foot candles. Each experimental house was equipped with a separate meter to record power consumption for lights and the two enclosed houses had, in addition, separate meters to record power consumption by the fans.

Temperature and relative humidity values in each of the experimental houses were monitored beginning eight weeks after the initiation of the trial and continuing through 40 weeks of the laying period. Thermocouples were installed in the cage area about six inches above the cage top in the center of each unit. Both wet and dry bulb readings were recorded at 2:00 a.m. and 2:00 p.m. daily.

Ammonia concentrations within each house were tested weekly utilizing a slightly modified method of Moum _et al_. (1969)[1/].

Data on egg production, egg weight, egg quality, shell thickness, feed efficiency and mortality were recorded. Birds were weighed by replicate at the beginning and end of the experiment. Where appropriate, the means of each parameter of all replicates of each treatment were calculated and analyzed by analysis of variance (Snedecor, 1946).

RESULTS AND DISCUSSION

Egg Production

As shown in Table 1, egg production was not significantly affected by differences due to housing, although the level of production was highest among birds in the open house. The mean hen-day production was 63.3 and 65.0 percent for birds in the enclosed houses with high (8-13 cfm per bird) and low (4.5-6.0 cfm per bird) ventilation rates, respectively, and 66.2 percent for birds in the open house. In a previous trial Herrick and Ross (1974) observed no differences in hen-day egg production between birds housed in enclosed and open houses. Baker (1969) and Harwood (1972) reported greater numbers of eggs among hens in enclosed housing compared to egg numbers from hens in open housing.

Feed Efficiency and Gain in Body Weight

The feed required to produce one dozen eggs was 3.98 and 3.96 lb. for birds in the enclosed houses exposed to high and low ventilation rates, respectively, and 4.15 pounds for birds in the open house (Table 1). Differences among treatments were not significant although birds in the enclosed houses were more

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[1/]Vineland Laboratories, Inc., Vineland, N.J.

efficient than those in the open house. These results agree with those of a previous trial at this station (Herrick and Ross, 1974) while Baker (1969) also reported increased efficiency among hens in enclosed housing in California when compared to hens in open housing.

Average gains in body weight were 0.12 and 0.09 pounds among birds in the enclosed houses exposed to high and low ventilation rates, respectively, and 0.06 pounds for birds in the open house (Table 1). These differences were not statistically significant.

Egg Weight and Egg Quality

Average individual egg weights were 2.09 and 2.08 oz. for eggs laid by birds in the enclosed houses with high and low ventilation rates, respectively, and 2.12 oz. for eggs laid by birds in the open house (Table 1). Differences among treatments were not statistically significant. These results are in agreement with those of Herrick and Ross (1974).

Albumen quality was measured in Haugh Units. The mean Haugh Units for eggs laid by birds in the enclosed houses with high and low ventilation rates were 88.2 and 88.9, respectively, and 86.0 for eggs laid by birds in the open house (Table 1). These differences in albumen quality were not statistically significant.

Shell thickness was not affected significantly by type of housing and ventilation rate, although shells were thinner among eggs laid by birds in both enclosed houses as compared with eggs produced by birds in the open house. Shell thickness of eggs laid by birds in both enclosed houses with mechanical ventilation averaged 0.0139 inches while the average shell thickness of eggs laid by birds in the open house averaged 0.0145 inches (Table 1).

Although differences in shell thickness were not statistically significant among treatments, there were significantly more cracked eggs recorded among birds in both enclosed houses than among eggs produced by birds in the open house. The incidence of cracked eggs averaged 7.11 and 6.66 percent among birds in the enclosed houses with high and low ventilation rates, respectively, while birds in the open house averaged 5.79 percent (Table 1). The significantly higher incidence of cracked eggs produced by birds in both enclosed houses may be related to the thinner shells of these eggs. Tyler and Geake (1960) and Bowman and Challender (1962) found a significant inverse relation between shell thickness and percentage of cracked eggs.

Mortality Rate

Mortality rates during the 52-week course of the experimental period among birds in the enclosed houses with high and low ventilation rates and the open house were 8.0, 6.8 and 13.2%, respectively. These differences were not significant statistically, although mortality was higher among birds in the open house. Other studies have also shown greater mortality among birds in open housing as compared to birds in enclosed housing (Baker, 1969; Harwood, 1972).

Environmental Data

Mean poultry house temperature and relative humidity values and ranges (Table 2) were calculated from daily measurements recorded at 2:00 a.m. and 2:00 p.m. throughout the 52-week course of the experiment. The 2:00 a.m. temperatures averaged 72.7, 71.9 and 72.1°F in the enclosed houses with high and low ventilation rates and the open house, respectively. Temperatures recorded at 2:00 p.m. averaged 79.6, 78.6 and 78.0°F in the enclosed houses with high and low ventilation rates and the open house, respectively. It is apparent that little variation occurred between environmental temperatures in the low ventilation rate enclosed house and the open house, however, temperatures were higher in the enclosed house with high ventilation rate especially during the afternoon. Although the roofs of the enclosed houses were designed to reflect solar heat, it appears that exposure of one end and side of the high ventilation rate house to the afternoon sun allowed solar heat entry and ventilation was insufficient to dissipate this heat from the house. The enclosed house with low ventilation rate was protected from the rays of the afternoon sun. It is important to note that although temperatures fluctuated as indicated by the ranges (Table 2), the average maximum temperatures were more than 5°F below maximums still considered satisfactory for maintaining production levels. Payne (1966) has shown that egg production need not suffer from constant temperatures as high as 86°F if nutrition formulations are considerate of level of voluntary feed intake. However, he observed a decrease in egg size among eggs laid by birds maintained at this temperature. In the present study, no significant depression in hen-day egg production or egg size occurred, although hens in the enclosed house with high ventilation rate produced fewer eggs (Table 1).

It is known that temperature and humidity interact to affect bird performance. Longhouse et al. (1960) recommended that maximum poultry house relative humidity not exceed 80 percent. Lampman et al. (1967) indicated a relative humidity of 60 percent is desirable if poultry house temperatures are in the 65-85°F range. The average maximum poultry house relative humidity in the present study averaged 89.8, 87.2 and 87.6 percent in the enclosed houses with high and low ventilation rate and open house, respectively, and the minimum relative humidity averaged 79.6, 79.2 and 80.0 percent in the enclosed houses with high and low ventilation rates and the open house, respectively.

Mean ammonia concentrations within each poultry house were calculated from weekly measurements and appear in Table 2. Ammonia concentrations were very low, ranging from 0 to 5 ppm among the three houses. These ammonia levels are well below the 20 ppm or more shown to affect chickens (Longhouse, et al., 1960 and Anderson, et al., 1964). It was necessary, however, to remove manure frequently from all houses to keep ammonia levels at this low level. Manure was removed from the enclosed houses approximately every 2 weeks while the open house was cleaned on the average of every 3 weeks.

As indicated previously, each enclosed poultry house was equipped with two separate electric meters to record power consumption required for light and the ventilation fan while power consumption for lights only was recorded in the open house. Total KWH consumption for light was 1455, 1386 and 1204 KWH for the enclosed houses with high and low ventilation rates and the open house, respectively (Table 2). The difference between the two enclosed houses was due to human error in adjusting the two dimmer switches, or variation in the meters. The higher power consumption for light in the enclosed houses is due to the need for higher intensity light during periods of egg collection and hand feeding and the full 14 hours per day of exposure to the dimmed light. The open house needed only about 1 to 3 hours per day of artificial light supplementation. The enclosed house with the fan set for maintaining the higher rate of ventilation utilized 1441 KWH of electricity while the fan in the house set to provide a lower rate of ventilation utilized only one-half this amount of electricity (770 KWH) as shown in Table 2.

APPLICATION OF RESULTS

Income from the sale of marketable eggs and spent hens and the cost of pullets, feed and electricity for hens in enclosed houses with high and low ventilation rates, respectively, and an open house are shown in Table 3. The average egg sale price used for calculation was 47.6 cents per dozen, the mean producer price during the experimental period as calculated from Hawaii Crop and Livestock Reporting Service data. The value of spent hens was obtained by multiplying the final body weight by 10 cents per pound based on the Hawaii poultry processors' mean 1972 price for stewing hens. The cost of pullets at the age of 20 weeks was estimated at $2.20 each. Feed was charged at $113.00 per ton ($124.56 per metric ton), the cost to the University of Hawaii for all ingredients. Electricity costs were calculated from Hawaiian Electric Company's general lighting and commercial air conditioning rate schedules for use of lights and ventilation fans, respectively.

Income[1/] over pullet, feed and electricity cost from maintaining birds in the enclosed houses with high and low ventilation rate was $2.49 and $2.72 per bird, respectively, and $2.52 per bird maintained in the open house (Table 3). Herrick and Ross (1974) reported a slightly greater income per bird over pullet, feed and electricity cost of two densities of layers in enclosed housing as compared to similar densities of birds in open housing. This was attributed to better feed efficiency among layers in enclosed housing which compensated for the increased consumption of electricity in the mechanically ventilated houses. Baker (1969) showed a greater return per hen in enclosed housing over those in open housing in California, and Harwood (1972) reported similar results from a North Carolina test.

[1/] Dramatic changes in feed and/or egg prices could significantly alter this income.

In the present study, the income derived from maintaining birds in the enclosed house ventilated at a low rate (4.5-6 cfm per bird) was greater than that of birds in either the enclosed house ventilated at a higher rate (8-13 cfm per bird) or the open house. The reason for the poorer performance of layers in the high ventilation rate enclosed house compared to those in the low ventilation rate enclosed house is not clear. The temperature and relative humidity differences were not great between these houses and none of the birds appeared to be particularly stressed. It did appear, however, from individual observations that ventilation rates in the enclosed houses were not always as calculated. Tradewinds blowing at the rate of 20 to 25 mph or more seemed to influence within-poultry house ventilation rate. This was particularly noticeable in the low ventilation rate house which was more exposed to these winds and ventilation rates appeared to be greater than those originally calibrated for the house. Also the distribution of incoming fresh air did not always appear to be adequate in the high ventilation rate house. Therefore, the ventilation rate differential originally calculated for the two enclosed units did not appear to remain constant. It was apparent that the ventilation scheme utilized in this study was subject to interference by the tradewinds to the extent that at times of briskly blowing tradewinds, the low ventilation rate unit actually appeared more comfortable. Based on these observations, it seems advisable to modify the ventilation system by placing the exhaust fans in the wall downwind of the prevailing tradewinds. This should minimize tradewind interference and improve the system of air exchange within the enclosed houses. In addition, reducing the size of the incoming air intake slot, or making it adjustable, would allow for increasing the speed of the incoming air. In this way a more constant and comfortable environment may be provided layers, thus further increasing bird efficiency and profitability from the utilization of enclosed poultry housing in Hawaii. Tests along this line are currently being conducted at this station.

REFERENCES

Anderson, D.P., C.W. Beard and R.P. Hamon, 1964. The adverse effects of ammonia on chickens, including resistance to infection with Newcastle disease virus. Avian Diseases 8:369-379.

Baker, A., 1969. Trend: Closed layer housing in California. Poultry Digest 28:554.

Bowman, J.C. and N.I. Challender, 1962. Egg shell strength. A comparison of two laboratory tests and field tests. Br. Poultry Sci. 4:103-116.

Drury, L.N., R.H. Brown and J.C. Diggers, 1964. Cooling poultry houses in the Southeast. Georgia Agri. Exp. Sta. Bul. N.S. 115.

Harwood, D.G., 1972. Economics of environmental control in broiler, egg production housing. Feedstuffs 44:40.

Herrick, R.B. and E. Ross, 1974. Effect of enclosed housing and bird concentration upon the performance of caged layers in Hawaii. Hawaii Agr. Exp. Sta. Res. Rpt. 201.

Lampman, C.E., J.E. Dixon, C.F. Petersen and R.E. Black, 1967. Environmental control for poultry housing. Idaho Agr. Exp. Sta. Bul. 456.

Long, J., A.C. Dale, R.B. Harrington and R.L. Johnson, 1966. The influence of selected temperatures and ventilation rates on egg production. Poultry Sci. 45:58-65.

Longhouse, A.D., G.O. Bressler, C.S. Shaffner and H.L. Garver, 1963. Poultry housing - Basic data useful for design purposes in the Northeastern states. West Virginia Agr. Sta. Bul. 486 T.

Moum, S.G., W. Seltzer and T.M. Goldhaft, 1969. A simple method of determining concentrations of ammonia in animal quarters. Poultry Sci. 48:347-348.

Parsons, R.A. and D.D. Bell, 1968. Summer operation of environmental poultry houses. California Agr. Ext. Ser. AXT 239.

Payne, C.G., 1966. Environmental temperature and egg production. Physiology of the Domestic Fowl. Ed. by C. Horton-Smith and E.C. Amoroso. Oliver and Boyd, Edinburgh.

Snedecor, G.W., 1946. Statistical Analysis. The Iowa State College Press, Ames, Iowa.

Tyler, C. and F.H. Geake, 1960. Studies on egg shells. XIII. Influence of individuality, breed, season and age on certain characteristics of egg shells. J. Sci. Fd. Agriculture 11:535-547.

Table 1. Mean Performance Data of Layers Caged in Enclosed Houses With Controlled Ventilation Rates and an Open House With Natural Ventilation.

Characteristic	Enclosed Houses		Open House
	High Controlled Ventilation	Low Controlled Ventilation	Natural Ventilation
Hen-day egg production (%)	63.3[a][1/]	65.0[a]	66.2[a]
Hen-housed egg production (%)	60.0[a]	62.4[a]	61.5[a]
Feed required to produce a dozen eggs, lb	3.98[a]	3.96[a]	4.15[a]
Gain in body weight, lb	.12[a]	.09[a]	.06[a]
Egg weight, oz	2.09[a]	2.08[a]	2.12[a]
Albumen quality (Haugh units)	88.2[a]	88.9[a]	86.0[a]
Shell thickness, 1 unit = .001 in	13.9[a]	13.9[a]	14.5[a]
Cracked eggs (%)	7.11[a]	6.66[a]	5.97[b]
Mortality rate (%)	8.0[a]	6.8[a]	13.2[a]

[1/]Values in the same line followed by the same superscript are not significantly different ($P < 0.05$).

Table 2. Environmental Data From Enclosed Houses With Controlled Ventilation Rates and Open House With Natural Ventilation.

Item	Enclosed Houses				Open House	
	High Controlled Ventilation		Low Controlled Ventilation		Natural Ventilation	
Temperature (°F)	Average	Range	Average	Range	Average	Range
A.M.	72.7	68-77	71.9	68-76	72.1	66-76
P.M.	79.6	71-84	78.6	72-83	78.0	69-82
Relative humidity (%)						
A.M.	89.8	80-99	87.2	72-99	87.6	81-99
P.M.	79.6	72-92	79.2	70-92	80.0	69-96
Ammonia concentration (ppm)	1.5	0-5	1.3	0-5	0.1	0-5
Electricity consumption						
Fan - Total KWH	1441		770		----	
Lights - Total KWH	1455		1386		1204	

Table 3. Income Over Pullet, Feed and Electricity Cost of Layers Caged in Enclosed Houses With Controlled Ventilation Rates and an Open House With Natural Ventilation.

Item	Enclosed Houses		Open House
	High Controlled Ventilation	Low Controlled Ventilation	Natural Ventilation
Income			
Egg sales (47.6¢/doz)[1]	$5,003.71	$5,206.49	$5,131.28
Salvaged hens (10¢/lb or 4.5¢/kg)[2]	206.70	209.43	194.50
Total	$5,210.41	$5,415.92	$5,325.78
Expenses			
Initial hen value ($2.20/hen)	$1,267.20	$1,267.20	$1,267.20
Feed cost ($113.00/ton or $124.56/metric ton)	2,359.44	2,444.19	2,527.81
Electricity[3]	147.36	134.83	76.16
Total	$3,774.00	$3,846.22	$3,871.17
Income over pullet, feed and electricity cost	$1,436.41	$1,569.70	$1,454.61
Income per bird housed over pullet, feed and electricity cost	$ 2.49	$ 2.73	$ 2.53

[1]Mean producer price 1972, Hawaii Cooperative Crop and Livestock Reporting Service.

[2]Hawaii Poultry Processors mean 1972 price, Hawaii Cooperative Crop and Livestock Reporting Service.

[3]Rates established by Hawaiian Electric Co. (1972).

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Departmental Paper 36–August 1975 (3m)